

# Update and plans on muon reconstruction

Dorota Stefan, Robert Sulej, Kevin Wood, Elizabeth Worcester

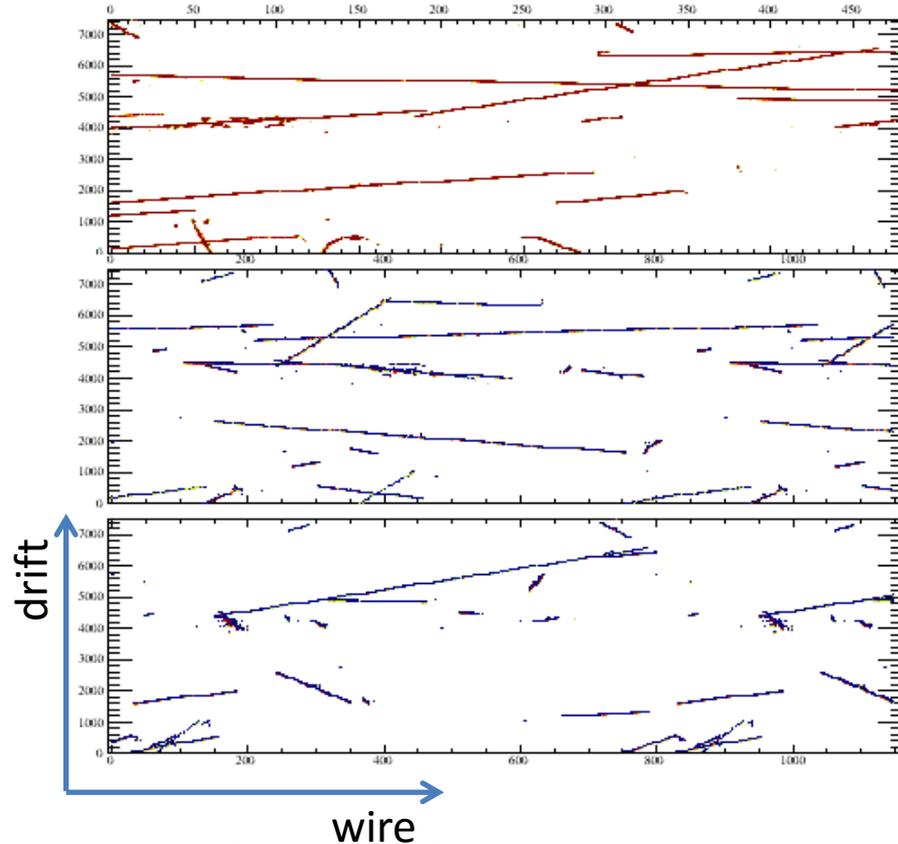
# Introduction

Large number of (not huge) tasks related to cosmic muons background to be taken.

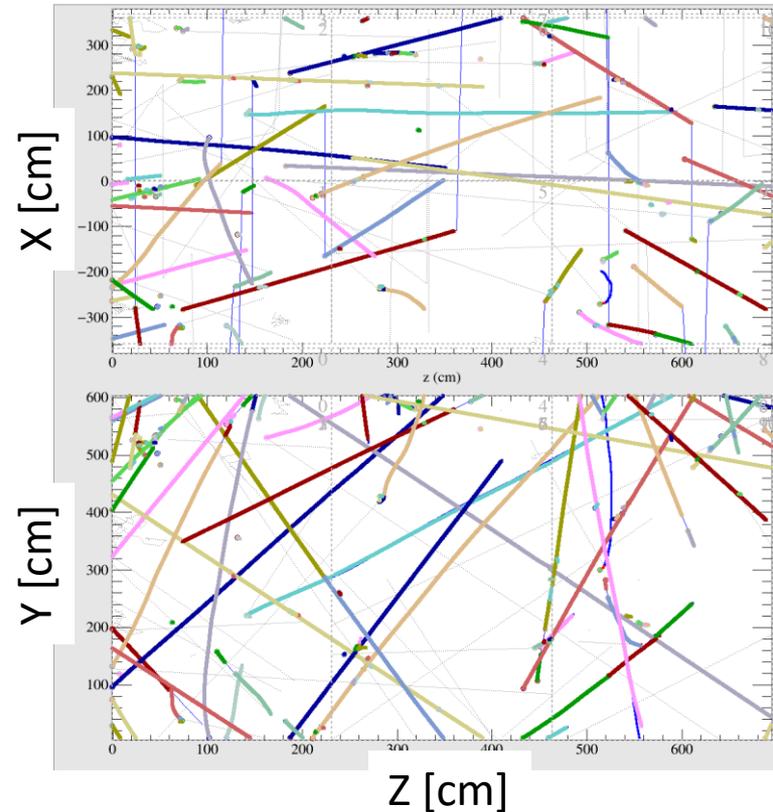
- Both beam and cosmic muons are interesting for physics studies.
- Need to evaluate fraction of beam events with too high overlay of cosmics for each physics study.
- Here would like to show a guidance how to estimate the **realistic** number of clean beam events (sufficiently separated from cosmic muons).
- Tasks can bring experience and develop into larger studies in ProtoDUNEs.

# Cosmic muons in protoDUNE

Raw signal



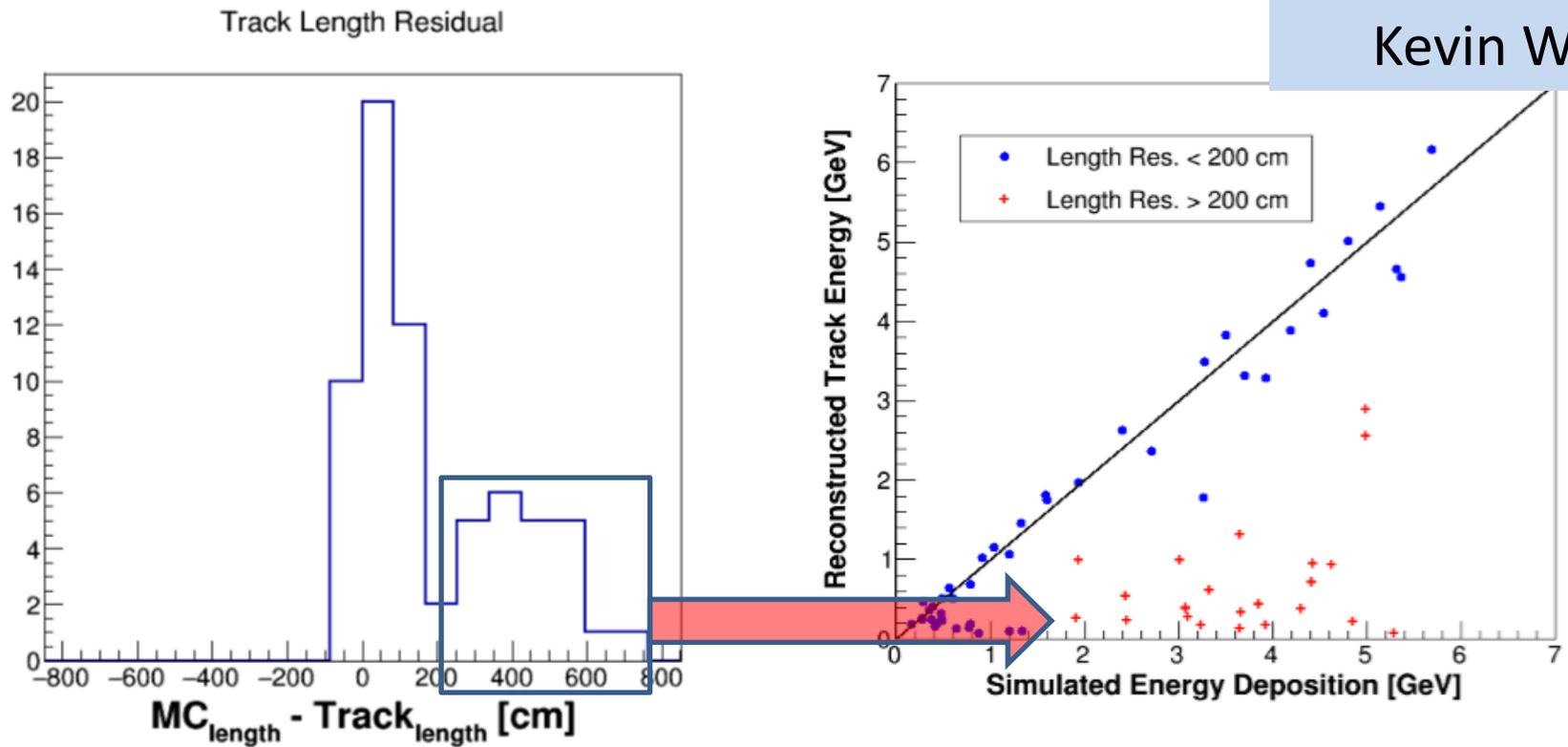
3D reconstruction



- Corsika simulation of cosmic, G4 and ProtoDUNE geom in LArSoft.
- Reconstructed cosmic are available (from E. Worcester): at FNAL DUNE disks ([/dune/data](#) or [/pnfn/dune/scratch](#)), and at CERN ([/eos/neutplatform/experiments/protoDUNE/mcpro/](#)).

# Efficiency of cosmic muons reconstruction

Kevin Wood

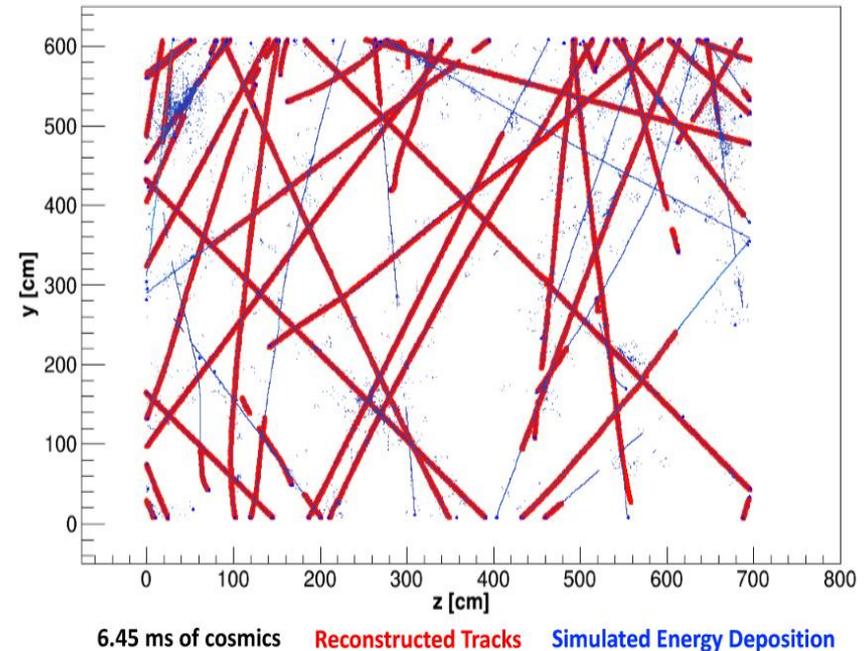


- Track finding coming up short.
- Failing to stitch across TPCs or inside TPC? → most likely CPA crossing (if there is no work on this, e.g. from 35t we need to add it to the list, it should be an easy algorithm) → generic algorithm which is independent from particular tracking input.

# Efficiency of cosmic muons reconstruction

Kevin Wood

- T0 should be the result of matching on both sides of cathode.
- Efficiency: separate in-TPC tracking from cross-TPC stitching → work may have continuation in muon selections for various studies.

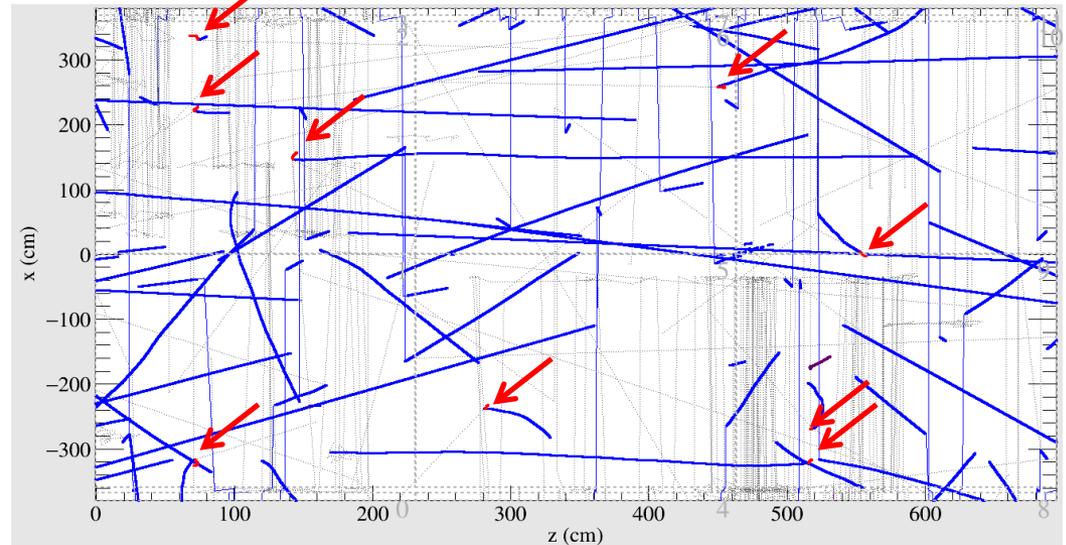


Module in `dunetpc/Protodune/`

← Good directory for protoDUNE specific modules (SP and DP).

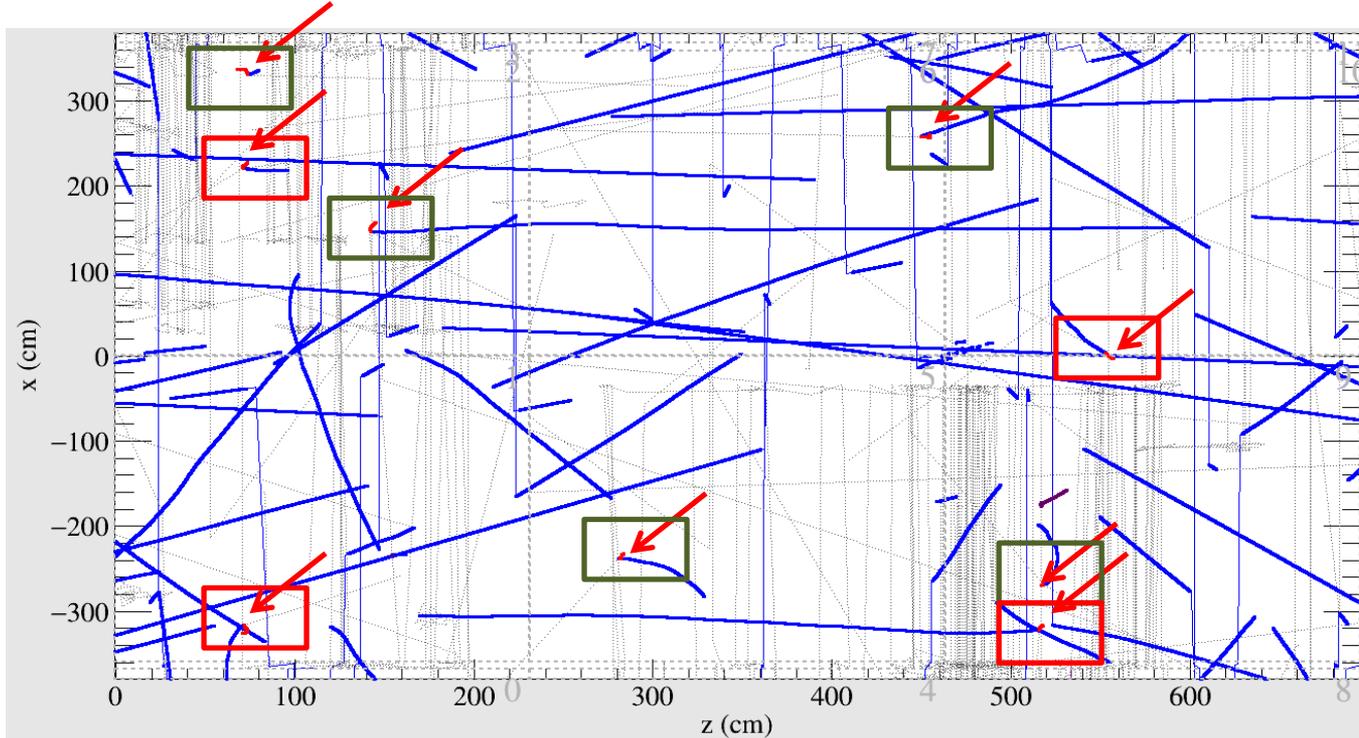
# Analysis of stopping muons and Michel electrons

- How many stopping muons should we expect in protoDUNE?
- The number can be estimated from simulation: analysis from Justin Hugon presented on protoDUNE calibration session.



# Stopping muons and Michel electrons – MC based studies

**How many of such events are clean enough to perform calorimetric measurements?**

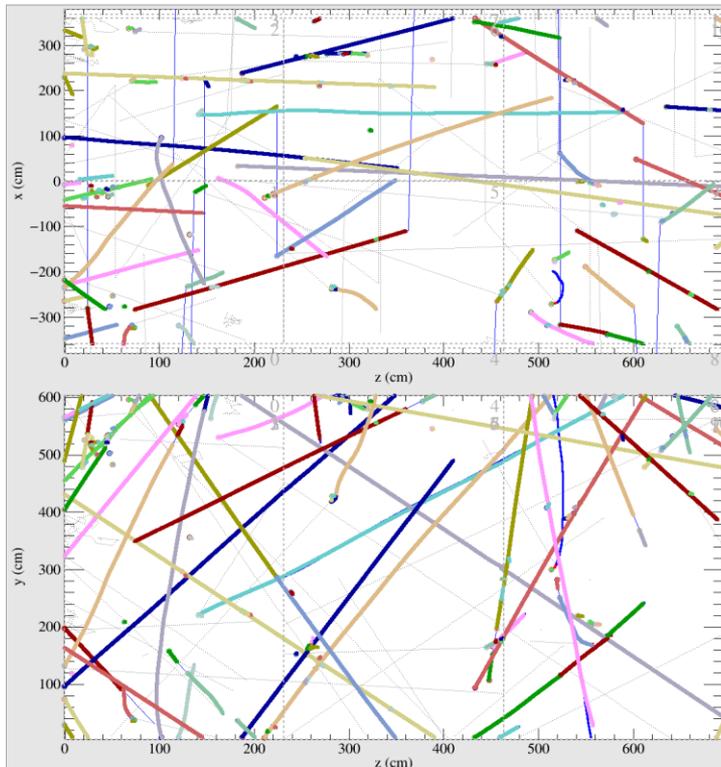


MC based studies with hits from reco are enough to provide rough estimation of useful events:

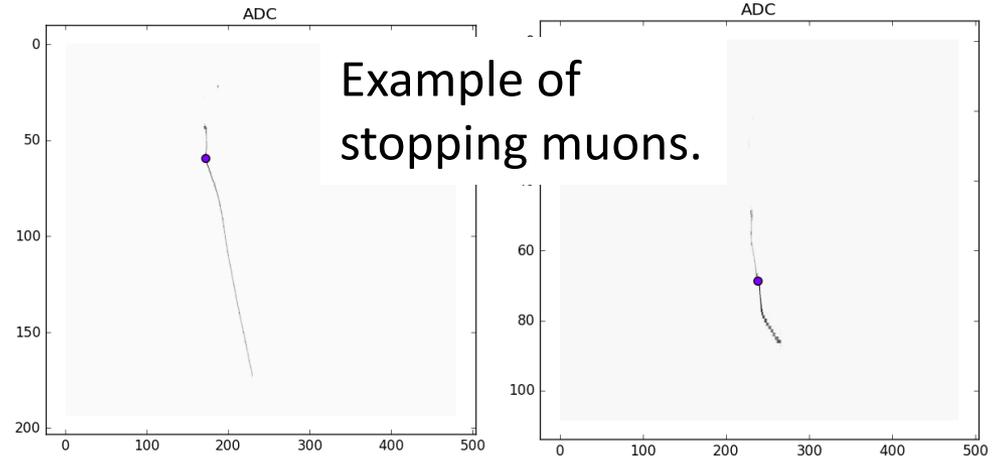
known 3D track & decay vertex  $\rightarrow$  projection to the wire plane  $\rightarrow$  check if there are hits that do not belong to muon track or Michel electron in close vicinity,

# Stopping muons and Michel electrons – reco studies

How are we going to proceed with data?



Offline TPC reconstruction  
(may be associated with  
muon tagger / PD system)



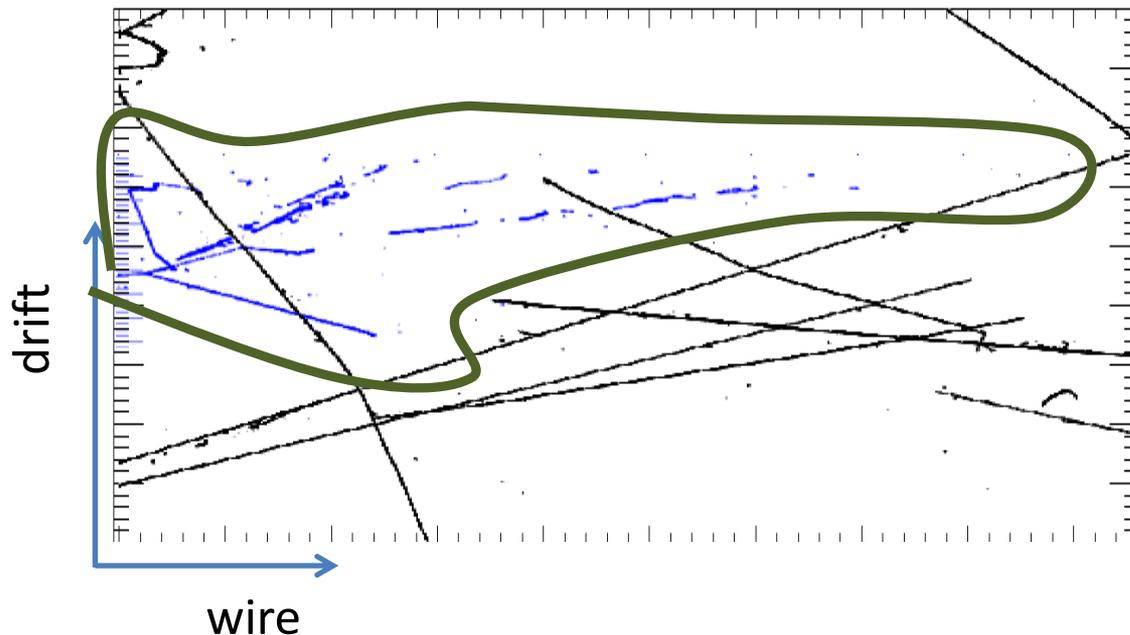
- Identification of stopping muons among crossing muons → **under development.**
- Check if the event is clean enough may be very similar to MC procedure.

# Beam particle event with cosmic muon overlay

**How many beam particle events are clean enough to perform physics measurements?**

- Energy scale studies: clean cascade at least in a view which is used for calorimetric measurements (needed studies: what is the acceptable amount of muon tracks overlapped with the cascade).
- Spatial reconstruction (at least two views have trajectories visible enough to be matched in reconstruction).

# Beam particle event with cosmic muon overlay



In analogy to cosmic muons fraction of clean beam events can be estimated from MC-based studies and reco-based studies using the same methods.

More challenging issue: distinguish muon related EM activity from the beam even parts.

# Particle beam data in protoDUNE

Different physics goals have different requirements on ProtoDUNE data samples (fraction of events clean from muons).

## Hadronic showers modeling:

- EM shower/tracks components: low muons overlaid, exact condition not known now.
- Cross sections: clean region up to the interaction vertex region.

## Proton decay studies (ref: [Michel Sorel](#)):

- PID of stopping particles – important to have the last part of a particle track.
- Electron/photon separation (e.g.  $p \rightarrow e^+ \eta, \eta \rightarrow \gamma \gamma$ ): initial part of cascades.
- Muon charge sign: end of tracks.

## Neutron-antineutron oscillations:

- Probably similar as for proton decay studies (need to define).

# Summary

- Analysis of cosmic muons is progressing, direction of work well defined, but people share time with other tasks so more help needed.
- Rough estimation of clean events can be done quickly, with MC-based studies and basic information from reconstruction (hits) → need to define „purity” requirements for different physics goals.
- We have available cosmic muon sim/reco root files at FNAL, and also at CERN.
- Experience from these tasks may be helpful to select clean events in real data.
- Finalizing decay tagging / separation between muon track and Michel electron → to be checked on real data.